



22116109

**CHEMISTRY  
HIGHER LEVEL  
PAPER 3**

Tuesday 10 May 2011 (morning)

1 hour 15 minutes

Candidate session number

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Examination code

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**INSTRUCTIONS TO CANDIDATES**

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options.
- Write your answers in the boxes provided.



0144

**Option A — Modern analytical chemistry**

- A1.** (a) One commonly used analytical technique is atomic absorption spectroscopy. State **one** use of this technique. [1]

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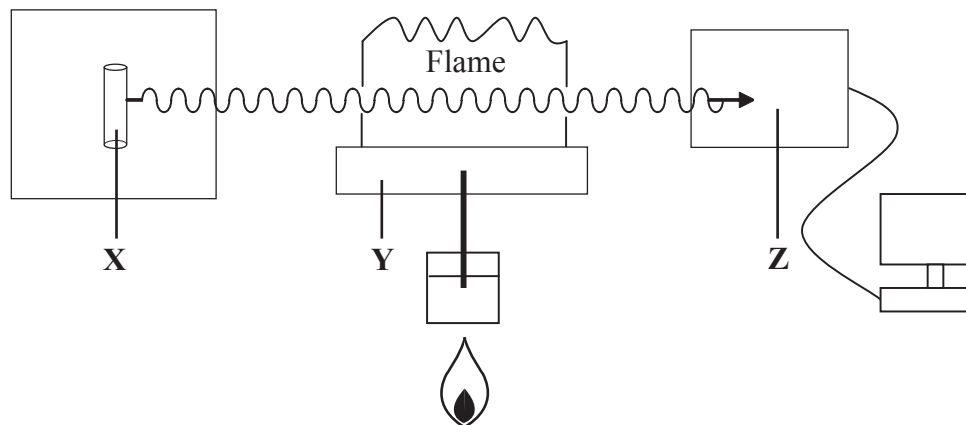
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(Question A1 continued)

- (b) The diagram below represents the components of an atomic absorption spectrophotometer. Identify the components marked **X**, **Y** and **Z** and explain their function in the analysis of a sample by this technique. [6]



**X** – Name:

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**X** – Function:

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**Y** – Name:

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**Y** – Function:

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**Z** – Name:

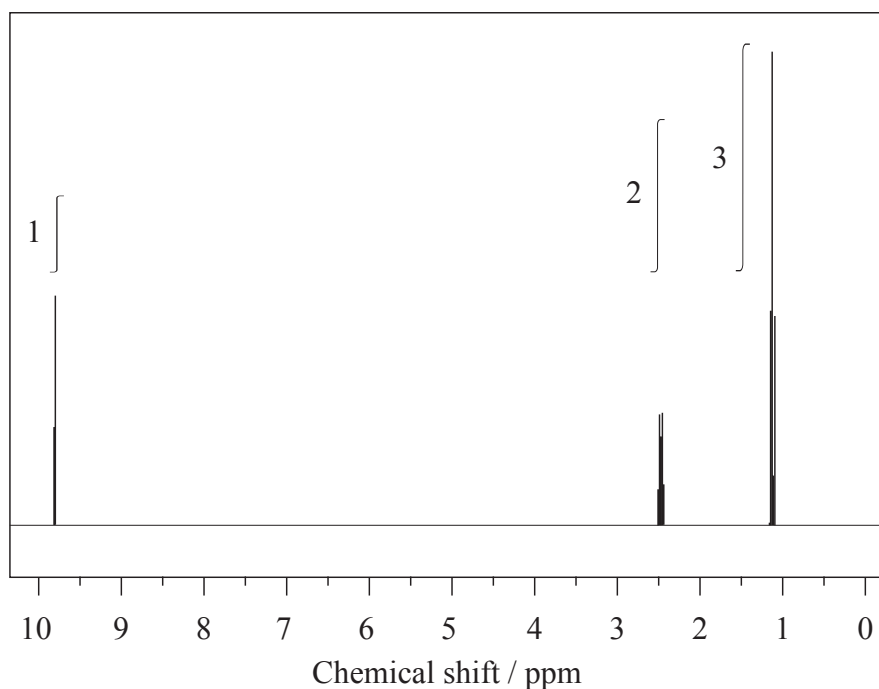
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**Z** – Function:

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**A2.** The  $^1\text{H}$  NMR spectrum of **X** with molecular formula  $\text{C}_3\text{H}_6\text{O}$  is shown below.



(a) Deduce which of the following compounds is **X** and explain your answer.

[2]



Compound:

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Explanation:

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(Question A2 continued)

- (b) State and explain the splitting pattern you would expect in a high resolution spectrum for the peak at 1.1 ppm. [2]

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- (c) The infrared and mass spectra for **X** were also recorded.

- (i) Apart from absorptions due to C–C and C–H bonds, suggest **one** absorption, in wavenumbers, that would be present in the infrared spectrum. [1]

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- (ii) Apart from absorptions due to C–C and C–H bonds, suggest **one** absorption, in wavenumbers, absent in this infrared spectrum but present in one of the other compounds shown in part (a). [1]

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- (d) Suggest the formulas and  $m/z$  values of **two** species that would be detected in the mass spectrum. [2]

Species: .....

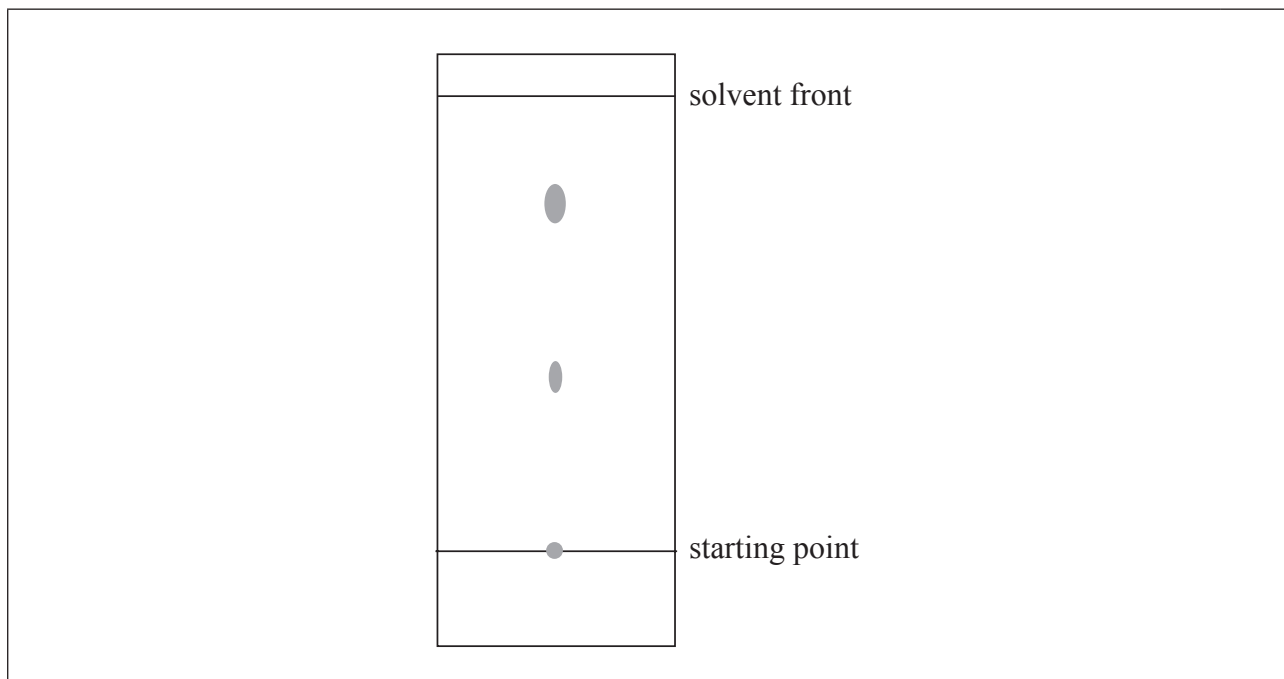
$m/z$ : .....

Species: .....

$m/z$ : .....



- A3.** A sample of food colouring was analysed using thin-layer chromatography to check whether it contained a banned substance. The  $R_f$  value of the banned substance is 0.25 under the same conditions.



- (a) Identify a stationary phase commonly used in thin-layer chromatography. [1]

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- (b) Predict where you would expect the banned dye to appear on the chromatogram and mark this spot with a circle on the diagram above. [1]

- (c) Describe how high performance liquid chromatography (HPLC) is carried out and why this results in the components of the mixture being separated. [3]

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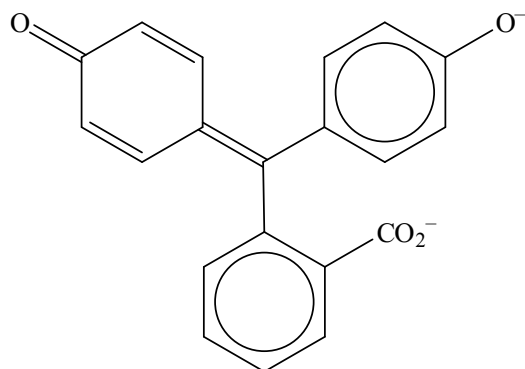
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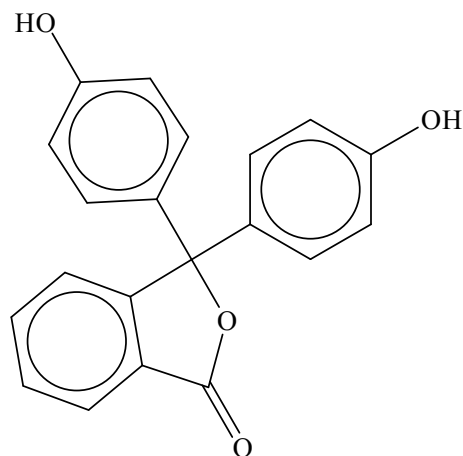
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- A4.** Phenolphthalein is colourless at pH 7 but its structure changes at pH 11 and it becomes pink. The structures of the compound at these two pH values are shown below.



Structure A



Structure B

- (a) Deduce the colours of the two structures and explain, in terms of the bonding, why one is coloured and the other is not. [2]

Structure A:

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Structure B:

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Explanation:

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(Question A4 continued)

- (b) Copper(II) sulfate forms a pale blue aqueous solution. When aqueous ammonia is added to this, initially a pale blue precipitate forms; this precipitate then dissolves in excess ammonia to form a deep blue solution. Explain why these solutions are coloured and the colour with excess ammonia is a deeper blue.

[3]

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**Option B — Human biochemistry**

**B1.** Starch and cellulose are polysaccharides found in plants.

(a) Compare the structural features of starch and cellulose.

[3]

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(b) Humans can digest starch but cannot digest cellulose. Explain why humans cannot digest cellulose.

[1]

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- [2]

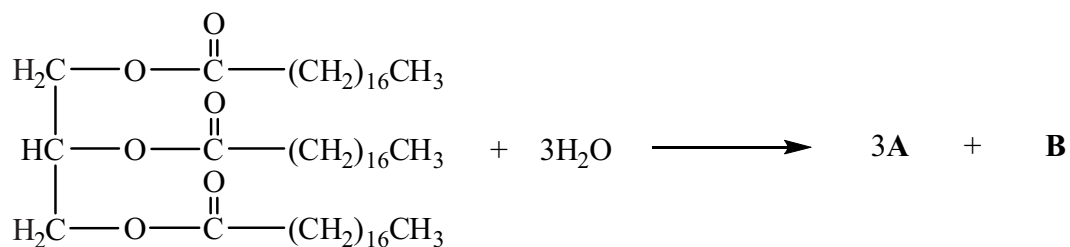
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- [2]



**B:**

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(Question B2 continued)

- (c) Deduce whether the fatty acid obtained in part (b) will have a higher or lower melting point compared to oleic acid,  $\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$ . Outline your reason. [2]

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- B3.** (a) Some synthetic hormones are similar in structure to progesterone and estrogen and may be used to prevent pregnancy. Outline the mode of action of these hormones as oral contraceptives. [3]

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- (b) Some other synthetic hormones are similar in structure to testosterone and are used as anabolic steroids. Outline **one** medical and **one** non-medical use of anabolic steroids. [2]

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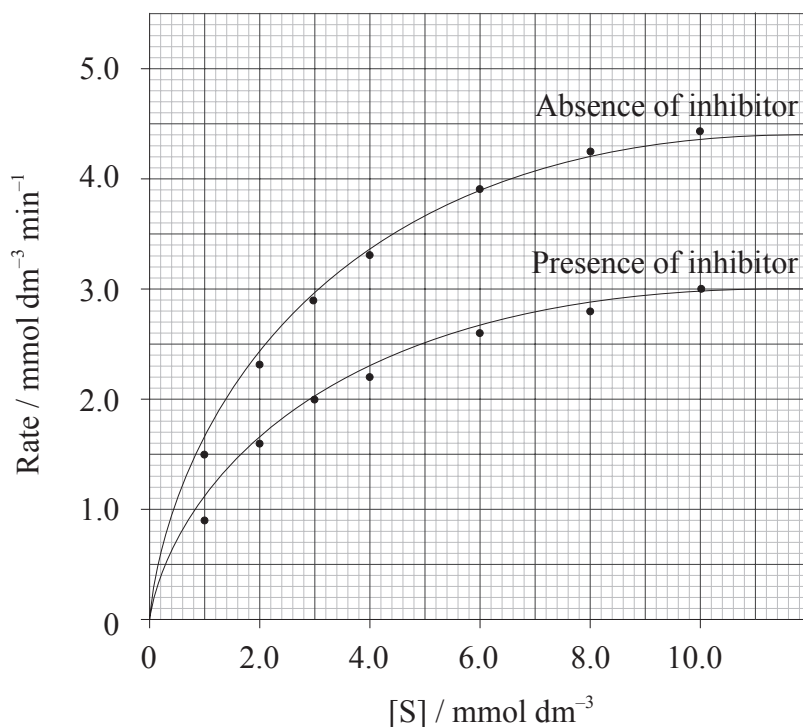
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- B4.** The kinetics of an enzyme-catalysed reaction are studied in the absence and presence of an inhibitor. The graph represents the initial rate as a function of substrate concentration.



- (a) Identify the type of inhibition shown in the graph.

[1]

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(Question B4 continued)

- (b) Determine  $V_{\max}$  and  $K_m$  in the absence of the inhibitor and in the presence of the inhibitor. [3]

Absence of inhibitor:

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Presence of inhibitor:

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- (c) Outline the relationship between  $K_m$  and enzyme activity. [1]

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**B5.** In aerobic respiration, the metabolism of glucose takes place using the processes of oxidation and reduction.

(a) Identify the molecule that undergoes oxidation and state the half-equation for the process. [2]

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(b) Identify the molecule that undergoes reduction and state the half-equation for the process. [2]

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(c) Identify **two** products that are formed when glucose undergoes anaerobic respiration in the presence of yeast. [1]

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**Option C — Chemistry in industry and technology**

**C1.** Many recent developments in chemistry have involved making use of devices that operate on a nanoscale.

- (a) (i) State the scale at which nanotechnology takes place and outline the importance of working at this scale. [2]

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- (ii) State **one** public concern regarding the development of nanotechnology. [1]

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- (b) One development has been the production of nanotubes. Describe the way in which the arrangement of carbon atoms in the wall and sealed end of a nanotube differ. [2]

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- C2.** (a) The initial products of the fractional distillation of oil often undergo cracking. This can be carried out in a number of ways. State the **major** reason for choosing each of the following techniques. [3]

Catalytic cracking:

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Thermal cracking:

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Steam cracking:

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- (b) Ethene is one of the major products of this process and much of it is converted to polyethene using the Ziegler-Natta process. State the catalysts used and the ways in which the conditions of this process differ from the free-radical polymerization process. [2]

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*(Question C2 continued)*

- (c) The polymers often have other substances added to modify their properties. One group of additives is plasticizers. State how plasticizers modify the physical properties of polyvinyl chloride and explain at the molecular level how this is achieved. [2]

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**C3.** Steel is a vital structural material in modern society. Some of it is obtained from recycled iron and steel, but much of it is produced from iron ore using a blast furnace.

- (a) Outline the process by which iron, produced in a blast furnace, is converted to steel. [3]

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- (b) Describe **one** heat treatment of steel and the way in which it alters the physical properties of steel. [2]

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- C4.** The chlor-alkali process, converting sodium chloride into chlorine and sodium hydroxide, is an important industrial process which is often carried out in a membrane cell.

For the membrane cell:

- (a) describe the function of the membrane. [1]

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- (b) state equations for the reactions at each electrode. [2]

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- (c) state **one** important use each for the chlorine and sodium hydroxide produced. [2]

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- C5.** Describe how silicon may be converted into a p-type semiconductor and explain why this leads to an increase in its electrical conductivity.

[3]

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**Option D — Medicines and drugs**

**D1.** Nicotine and caffeine are commonly classified as stimulants.

- (a) State the name of **one** functional group which is present in caffeine but absent in nicotine. [1]

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- (b) Other than methyl groups, state the name of **one** functional group present in both caffeine and nicotine. [1]

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- (c) State **two** symptoms associated with caffeine being consumed in large amounts. [1]

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- (d) (i) Outline the meaning of the term *sympathomimetic drug*. [1]

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- (ii) State **one** example of a sympathomimetic drug other than nicotine. [1]

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**D2.** Two substances commonly used in antacid tablets are magnesium hydroxide and aluminium hydroxide.

- (a) State an equation to represent a neutralization reaction with one of the above antacids. [1]

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- (b) State and explain whether 0.1 mol of magnesium hydroxide is more effective or less effective than 0.1 mol of aluminium hydroxide. [1]

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- (c) Explain why alginates and dimethicone are often included in antacid tablets. [2]

Alginates:

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Dimethicone:

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**D3.** (a) State **two** differences in structure between viruses and bacteria.

[2]

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(b) Describe **two** ways in which antiviral drugs work.

[2]

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(c) Discuss **two** difficulties associated with the development of drugs for the effective treatment of AIDS.

[2]

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**D4.** Some mind-altering drugs contain the indole ring. The structures of indole and some mind-altering drugs are shown in Table 20 of the Data Booklet.

- (a) In terms of functional groups, state **two** similarities in the structures of LSD, psilocybin and mescaline. [2]

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- (b) State the names of **two** functional groups that are present in LSD but not in mescaline. [2]

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- (c) Identify the active ingredient present in cannabis. Explain why a doctor may prescribe this active ingredient to some patients. [2]

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**D5.** Drugs such as fluoxetine and aspirin can be converted into salts.

- (a) Identify the functional group present in **each** of fluoxetine and aspirin which allows them to be converted into a salt. Suggest a reagent required for each conversion. [2]

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- (b) Explain the advantage of converting drugs such as fluoxetine and aspirin into salts. [2]

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**Option E — Environmental chemistry**

**E1.** The two major acids that cause acid rain originate from different sources.

Outline the process responsible for the production of each acid and state an equation to show its formation.

[4]

Acid 1:

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Acid 2:

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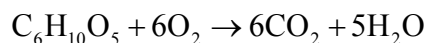


**E2.** Organic matter present in water can be decomposed under aerobic and anaerobic conditions by bacteria.

- (a) Identify the product, different in each case, when compounds containing the following elements are subjected to aerobic and anaerobic conditions. [4]

Element	Aerobic decomposition	Anaerobic decomposition
Carbon		
Nitrogen		
Sulfur		
Phosphorus		

- (b) In a certain lake, anaerobic conditions exist due to the presence of 10 ppm by mass ( $0.010 \text{ g dm}^{-3}$ ) of organic matter. Determine the mass of oxygen required to oxidize the organic matter in  $1 \text{ dm}^3$  of water. Assume that the aerobic decomposition process can be represented by the following equation. [2]



- E3.** (a) Outline a condition that leads to the production of carbon monoxide, CO, in an internal combustion engine. [1]

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- (b) State an equation for the reaction that takes place between CO and a primary pollutant in a catalytic converter of an internal combustion engine. [2]

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- (c) Identify the environmental problem associated with one of the products formed in part (b) [1]

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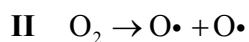
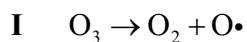
- (d) Other than the use of a catalytic converter, state **two** methods of controlling CO emission from an internal combustion engine. [1]

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- E4.** (a) The following reactions take place in the ozone layer by the absorption of ultraviolet light.



State and explain, by reference to the bonding, which of the reactions, **I** or **II**, requires a shorter wavelength. [2]

- (b) CFCs and  $\text{NO}_x$  are pollutants responsible for the depletion of the ozone layer. Discuss the role of  $\text{NO}_x$  in this process and include equations for a stepwise mechanism. [3]



- E5.** (a) State what is meant by the term *cation exchange capacity (CEC)* of soil. [1]

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- (b) The CEC of soil depends on the pH. Explain how the availability of nutrients is affected at low pH. [2]

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- (c) In an acidic soil, nitrate ions may undergo reduction to form ammonium ions. Deduce a half-equation for the reaction and state **one** disadvantage of this reaction for plant nutrition. [2]

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**Option F — Food chemistry**

**F1.** Fats and vegetable oils are triesters of glycerol with fatty acids. Many of these acids contain 18 carbon atoms. The table shows the relative percentages of various  $C_{18}$  fatty acid chains in four common fats and oils.

Fat/Oil	$C_{17}H_{35}COO-$ / %	$C_{17}H_{33}COO-$ / %	$C_{17}H_{31}COO-$ / %	$C_{17}H_{29}COO-$ / %
Tallow	52	44	3	1
Linseed Oil	5	32	18	45
Olive Oil	2	83	15	0
Peanut Oil	7	47	46	0

(a) Deduce which fat or oil from the table could best be described as: [2]

saturated

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mono-unsaturated

.....

poly-unsaturated.

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(b) Explain the meaning of the term *shelf life*. [1]

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(Question F1 continued)

- (c) The shelf life of vegetable oils is often limited by auto-oxidation, which initially forms hydroperoxides. Outline the mechanism by which hydroperoxides are formed and state a class of compounds, formed from hydroperoxides, that are responsible for the off flavours produced in food. [4]

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- (d) State the name, and briefly explain the action, of an artificial antioxidant that can be added to reduce the rate at which hydroperoxides are formed. [2]

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- (e) Hydrogenation can result in the formation of trans fatty acids. Outline the meaning of the term *trans fatty acids* and explain why their formation is undesirable. [2]

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**F2.** Anthocyanins and carotenes are both coloured substances found in many foods.

- (a) Explain, in terms of their molecular structure, why these compounds are coloured. [1]

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- (b) State a common food, apart from carrots, in which the following classes of pigment are found. [2]

An anthocyanin:

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A carotene:

.....

- (c) Identify **one** other coloured compound commonly found in uncooked foods. [1]

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- (d) Countries have different laws about the use of synthetic colourants in food. Explain why this can be dangerous for the consumer. [1]

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**F3.** Many food items contain genetically modified ingredients.

(a) Explain what is meant by the term *genetically modified food*.

[1]

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(b) Describe **two** advantages and **one** concern about the use of genetically modified food.

[3]

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**F4.** The stereochemistry of molecules affects the way they interact with taste and smell receptors in the body.

(a) State **one** example of a compound and its enantiomers with different tastes or smells. [2]

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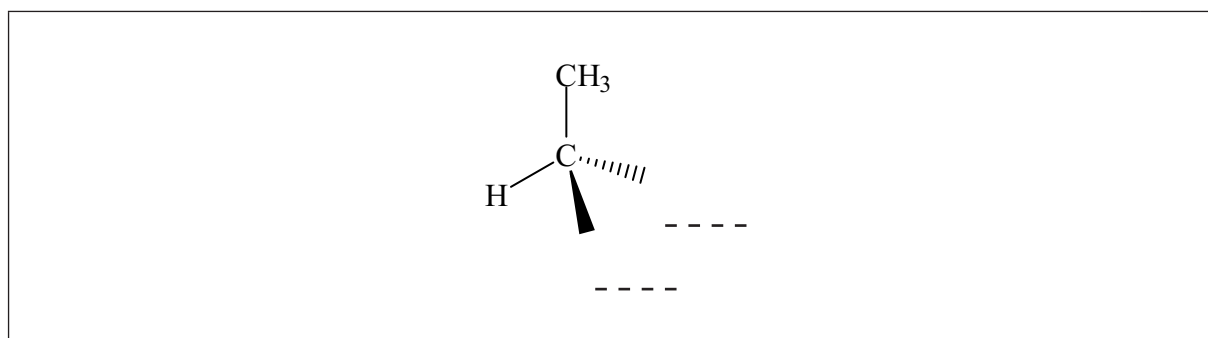
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(b) The stereochemistry of carbohydrates and amino acids is usually indicated by the D/L convention.

(i) Alanine has the formula  $[H_2N-CH(CH_3)-COOH]$ . Deduce the structure of D-alanine and complete its structure below. [1]



(ii) State which convention is usually employed to indicate the stereochemistry of molecules other than carbohydrates and amino acids. [1]

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(iii) Based on the structure given in part (b) (i) comment on the statement “D-alanine is a  $+(d)$  compound”. [1]

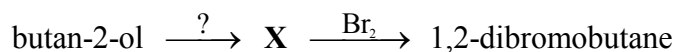
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**Option G — Further organic chemistry**

- G1.** Butan-2-ol cannot be directly converted to 1,2-dibromobutane. The conversion can be carried out in two stages by first converting butan-2-ol into **X**, which is then reacted with bromine.



- (a) State an equation and the conditions needed for the conversion of butan-2-ol into **X**. [2]

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- (b) Describe the mechanism of the second stage of the conversion, which occurs when bromine is added to **X**, using curly arrows to show the movement of electron pairs. [3]

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*(Question G1 continued)*

- (c) Butan-1-ol could be used instead of butan-2-ol. Compare the yield of 1,2-dibromobutane expected for butan-1-ol with that obtained for butan-2-ol. Explain your answer. [2]

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**G2.** (a) Describe the mechanism for the reaction of water with ethanoyl chloride.

[4]

(b) State the formula of the product formed when 2-chloropropane reacts with magnesium to form a Grignard reagent and state the conditions required for this reaction to occur.

[2]

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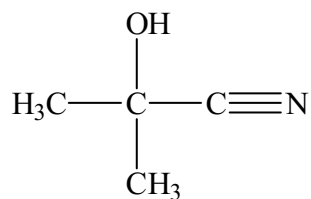
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(Question G2 continued)

- (c) Grignard reagents are often used to increase the length of the hydrocarbon chain in molecules. An alternative way of doing this is to use cyanohydrins such as:



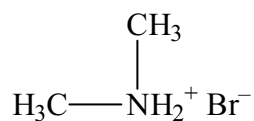
- (i) State the reagents that react to produce this compound. [1]

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- (ii) Draw the structural formula of the organic compound that is produced by the hydrolysis of this cyanohydrin. [1]



- G3.** (a) State the class of compounds to which the substance below belongs and deduce a balanced equation for its reaction with aqueous sodium hydroxide. [2]



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- (b) Explain how the pH of an aqueous solution of the organic product from part (a) would compare with the pH of aqueous ammonia of the same concentration. [2]

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- G4.** (a) Describe the mechanism for the reaction of benzene with chlorine, using curly arrows to show the movement of electron pairs, including the role of any other substance required for the reaction to occur. [4]

- (b) Methylbenzene and nitrobenzene also react with chlorine under similar conditions. Explain the relative rates at which these two reactions occur. [2]

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